

BELLCOMM. INC.

SUBJECT: Orbital Workshop Configuration Changes to Enhance Performance Characteristics - Case 103-3

DATE: October 14, 1966

FROM: M. S. Feldman  
L. A. Ferrara  
P. H. Whipple

ABSTRACT

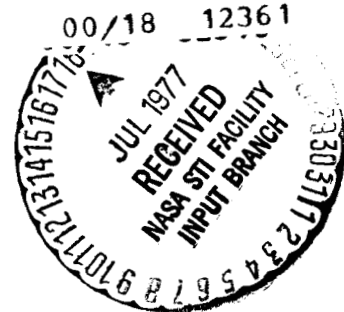
The orbital workshop mission is examined from the viewpoint of improving payload weight margin and performance through substituting solar cells and batteries for the augmented fuel cell cryogenic supply in the Airlock Module. Tradeoffs show that approximately 1200 pounds can be saved by this substitution. A further examination is made to ease the resupply problem by placing all consumables on the resupply CSM and further improving the weight margin. Finally, a 2-gas atmosphere option is analyzed and indicates the weight penalty associated with this modification is within the weight margins achieved through the electrical power system reconfiguration.

It is concluded that the solar cell/battery configuration will effect a weight savings sufficient to provide an orbital lifetime of 400 days thus providing flexibility in planning for subsequent missions.

(NASA-CR-153660) ORBITAL WORKSHOP  
CONFIGURATION CHANGES TO ENHANCE PERFORMANCE  
CHARACTERISTICS (Bellcomm, Inc.) 10 p

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## MEMORANDUM FOR FILE

### Introduction

It has recently been suggested that the orbital workshop program include solar cell power and 2-gas systems in order to improve the configuration for revisit and reuse. The current baseline program calls for the workshop to be flown on Alternate Mission 209 and to be revisited and reused by Missions 210, 211, 212 and 213.

The program is constrained to a very minimum modification to the CSMs for 209 and 210; to slightly more modification for 211 and 212; and perhaps even more modification for 213. It was, however, assumed that, in spite of the Airlock's "almost to contract" status, configuration changes might be possible. In analyzing and reporting the effect of these suggestions, 209, 211 and 213 have been used to designate configurations with an increasing amount of modification to the CSM and Airlock Module.

### Power Requirements

The electrical power requirements for the nominal 28-day, 3-man SAA-209 mission are listed below based on Reference 1.

<u>Module</u>	<u>Peak Power(kw)</u>	<u>Avg. Power(kw)</u>
CSM	4.5	1.6
Airlock Module		.6
Experiments	2.4	<u>.5</u>
		2.7 kw

The following assumptions and systems characteristics were used in this analysis.

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1. The Block II Apollo fuel cells and associated reactant supply will operate continuously for at least 28 days furnishing approximately 640 kw-hrs of energy and 450 pounds of potable water at a minimum power level of 450 watts per fuel cell power plant, two power plants active "on line" and the third in a "hot" standby condition.
2. Operational requirements will permit the solar cells mounted on the SLA panels to be exposed almost perpendicular to the solar radiation vector whenever the spacecraft is out of the earth's shadow.
3. Peak power demands from the various spacecraft subsystem can be programmed so that all peak demands will not occur simultaneously and will not be more than 5 kw.
4. Solar cells are arranged in series parallel combinations so that the effect of possible meteoroid impact damage is minimized, and an average of 9 watts of power is produced per square foot of projected area at 1.0 AU.

The following table summarizes the solar cell/battery-augmented cryogenic supply tradeoff based on the foregoing parameters and characteristics.

1. Power required	2.7 kw(avg) 5.0 kw peak
2. Battery energy to be furnished during dark-side passage (.7 hr max duration, .9 kw furnished by FCP)	1.3 kw-hr
3. Battery weight @25 w-h/lb Ni-Cd cells; 20% depth of discharge	250 lbs
4. Solar cell energy to be furnished (peak load 5.0 kw less FCP contribution .9 kw plus average battery recharge 1.8 kw)	5.9 kw
5. Solar cell projected area required based on 9 w/ft <sup>2</sup>	655 ft <sup>2</sup>
6. Percent of SLA projected area utilized	70%
7. Total solar cell weight @.6#/ft <sup>2</sup>	425 lbs

### Configurations

Three consecutive configurations and their performance characteristics are defined. The 209 solar cell configuration considers the addition of solar cells mounted on SLA panels and batteries mounted on the Airlock and the deletion of reactants and reactant system in the Airlock needed to supply the CSM fuel cells. The 211-CSM resupply configuration considers the effect of moving all life support expendables in the Airlock to the CSM. The 213-2 gas system configuration considers adding a nitrogen supply to the CSM to supply a 5 psia 70% oxygen-30% nitrogen environment to the CSM/Airlock/Spent S-IVB stage.

The configuration selected as a baseline for this memorandum includes an uprated Saturn I launch vehicle, Block II CSM, SLA, Airlock and Experiments as indicated in Reference 2. Tables 1 and 2 show the 209 baseline spacecraft inert weight to be 36,253 pounds with a negative margin of 303 pounds, the orbital altitude to be 230 n.m. and the lifetime to be 180 days.

### 209 Solar Cell Configuration

This configuration considers the effects of deleting the cryogenic fuel cell reactant supply from the Airlock, adding photovoltaic cells on the SLA panels and adding a bank of batteries to the Airlock. The following assumptions were used in development of this configuration.

1. The SLA panels could be folded back and locked at right angles to the CSM/AM/S-IVB spacecraft longitudinal axis.
2. The inside surface of the four SLA panels are available to mount solar cells.
3. As in the baseline configuration, an electrical umbilical will be installed after transposition and docking of the spacecraft to permit transfer of electrical energy between the CSM and the AM/S-IVB.

The inert weight for this spacecraft configuration is shown in Table 1 to be 35,017 pounds which is 1236 pounds lighter than the baseline weight. A summary of the weight additions and deletions is shown below.

### Weight Added (solar cell system)

Solar Cells	425
Fittings	25
Batteries	250
Power Conditioning Eqt.	85
Wiring	<u>55</u>
	840 lbs

Weight Deleted (cryogenic storage)

Reactants	1134
Tanks	710
Installation, MTGS and Fittings	155
Gas Umbilical	<u>77</u>
	2076 lbs

Weight Saved

$$2076 - 840 = 1236 \text{ lbs}$$

Referring to Table 2, it can be seen that the 209 solar cell configuration can be injected into an 80 x 262 n.m. orbit, and sufficient SPS fuel is available to circularize the orbit at 262 n.m. The launch vehicle injection capability into an 80 x 262 n.m. orbit is 70,351 pounds. With the required injected spacecraft weight from Table 2 of 38,930 pounds, including SPS fuel and the S-IVB/IU weight of 31,421 pounds, it is seen that the launch vehicle capability is just sufficient for the circular orbital altitude chosen. This spacecraft can be expected to have a lifetime at this altitude of about 400 days which is sufficient for a number of revisits.

211-CSM Resupply Configuration

If the orbital workshop is to be reused on subsequent missions, it must be resupplied with life support expendables. The resupply vehicle will probably be a modified CSM. In future planning, it might, therefore, be desirable to standardize on a CSM/Airlock configuration in which all expendables are carried in the CSM rather than divided between the CSM and Airlock.

The 211-CSM resupply configuration considers the effects of modifying the 209 solar cell configuration by moving all life support expendables in the Airlock to the CSM. Table 1 shows an additional weight savings of 374 pounds for this configuration. The weight deleted from the Airlock for this configuration is itemized below:

Oxygen	1088 lbs
Tanks and System	736 lbs
LiOH	250 lbs

The weight added to the CM is 250 pounds for LiOH. The weight added to the SM is 1450 pounds for oxygen, tank and system.

This configuration has the disadvantage of requiring the development and design of a new spherical oxygen tank to be installed in Sector 1 of the SM.

This spacecraft configuration can be injected into a 80 x 270 n.m. transfer orbit. The total injected weight capability of the launch vehicle is about 70,271 pounds. The required total injected spacecraft weight from Table 2 is 38,850 pounds including SPS fuel. With the S-IVB/IU injected stage weight of 31,421 pounds, the launch vehicle injected capability is matched with a resulting zero injected weight margin. The orbital lifetime of the spacecraft at 270 n.m. is about 470 days.

#### 213-2 Gas Atmosphere Configuration

As future mission objectives increase the complexity of operation and lengthen the crew stay times, it may become desirable to utilize some of the system weight margin toward the installation of a 2-gas atmosphere system. Such a mission could serve as a test bed for very long duration manned missions further downstream in the program. The orbital workshop mission was examined for the weight penalties that would be associated with conversion of the pure oxygen atmosphere to a 5.0 psia 70% oxygen 30% nitrogen atmosphere. Such a system is identified as the 213-2 Gas Atmosphere Configuration. As shown in Table 1, this configuration results in a SM weight increase over the previous configuration of 435 pounds. These weight changes over the 211-CSM resupply configuration are distributed as follows:

	<u>Nitrogen(lbs)</u>
Airlock Module Pressurization	8.8
S-IVB Pressurization	86.8
CSM Leakage	35.4
S-IVB Leakage	106
Airlock Leakage	<u>9.5</u>
Total Added Gas-Nitrogen	240 lbs
Residuals	<u>15</u>
	255
Tanks and Fittings	<u>180</u>
Total	435 lbs

This spacecraft can be injected into a 80 x 254 n.m. transfer orbit with subsequent circularization at apogee. The

launch vehicle total weight injection capability into this transfer trajectory is 70,431 pounds for this orbit, giving a zero injected weight margin. Expected orbital lifetime for the spacecraft at this altitude is about 340 days.

#### Summary

If the current requirements for SAA-209 are not modified by decreasing experiment payload or changing the Airlock Module configuration, the launch vehicle does not have sufficient capability to inject the spacecraft into a high enough orbit to achieve long orbital lifetime.

Modifying the Airlock power system has the potential of reducing spacecraft weight by 1236 pounds. This modification involves the deletion of fuel cell cryogenics and system from the Airlock and the addition of a solar cell and battery electric power system. This configuration adheres to the program constraint of minimum modification to the CSM and can provide an orbital lifetime of 400 days which provides large flexibilities in subsequent mission planning. The vehicle could be left in a powered down but active status between visits.

An additional weight savings of 374 pounds can be achieved by transferring all expendable storage from the Airlock to the CSM. This modification has the disadvantage of requiring a new design and fabrication of an oxygen tank for installation in Sector 1 of the SM. It does, however, have the capability of performing the resupply function that is required if the Airlock/Orbital Workshop is to be reused on subsequent missions.

It is also shown that the weight penalty associated with the installation of a 2-gas life support system in the CSM to supply CSM/Airlock/Orbital Workshop can be accommodated with the margin supplied by the electrical power modification. This configuration would, however, require extensive CSM modification and would, therefore, be relegated to a follow-on program rather than the 209-212 missions.

  
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Attachments (see next page)

209 BASELINE WEIGHT		209 SOLAR CELL			211-CSM RESUPPLY			213-2 GAS SYSTEM		
PARTS	TOTALS	ΔWT	PARTS	TOTALS	ΔWT	PARTS	TOTALS	ΔWT	PARTS	TOTALS
	22953			22953	+1700		24653	+435		25088
11704			11704		+250	11954			11954	
11249			11249		+1450	12699		+435	13134	
	3800	+450		4250			4250			4250
	8000	(-1686)		6314	-2074		4240			4240
2486			2486			2484			2484	
3900		(-2076)	1824		(-1824)	0			0	
200		+390	590			590			590	
612			612			612			612	
202			202			202			202	
600			600		(-250)	339			339	
	1500			1500			1500			1500
	36253	(-1236)		35017	(-374)		34643	+435		35078

CSM  
CM  
SM  
SLA  
AIRLOCK  
STRUCTURE  
CRYOGENIC SUPPLY  
ELECTRICAL  
ENVIRONMENT  
ELECTRONICS  
FURNISHINGS & GFE  
EXPERIMENTS

TOTAL SPACECRAFT

SPACECRAFT INERT WEIGHT

TABLE 1

209 BASELINE	209 SOLAR CELL	211 CSM RESUPPLY	213-2 GAS SYSTEM
31421	31421	31421	31421
24821	24821	24821	24851
950	950	950	950
4150	4150	4150	4150
1500	1500	1500	1500
36253	35017	34643	35078
22953	22953	24653	25088
3800	4250	4250	4250
8000	6314	4240	4240
1500	1500	1500	1500
67674	66438	66064	66499
230	262	270	254
3300	3913	4207	3932
1800	2165	2235	2065
1500	1748	1972	1867
70974	70351	70271	70431
70671	70351	70271	70431
-303	0	0	0
180	400	470	340

# PERFORMANCE CAPABILITY

TABLE 2

PERFORMANCE DATA BASED ON DUE EAST LAUNCHES FROM KSC AND DATA FROM REFERENCE 3. ORBITAL LIFETIMES BASED ON DATA FROM REFERENCE 2.

S-IVB/IU

S-IVB  
MODS  
IU  
FPR

SPACECRAFT

CSM  
SLA  
AM

EXPERIMENTS

TOTAL WEIGHT(LESS SPS PROPELLANT)

CIRCULAR ORBIT ALTITUDE(N.M.)

SPS PROPELLANTS

CIRCULARIZATION  
RETRO

INJECTION WEIGHT(80 N.M. PERIGEE)

INJECTION CAPABILITY(80 N.M. PERIGEE)

MARGIN

LIFETIME(DAYS)

**BELLCOMM, INC.**

REFERENCES

1. McDonnell Aircraft Corporation, "Spent Stage Experiment Support Module", Vol. I, Report No. E559, June 17, 1966
2. K. E. Martersteck, "Flight Performance Estimate for SAA Mission 209 - Case 103-3", Bellcomm Memorandum for File, September 30, 1966
3. NASA Certified Launch Vehicle Data, Saturn IB Launch Vehicle, attachment to memo of MA to MD-P dated March 21, 1966